



## PATENT APPLICATION

### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Mohsen Shahinpoor  
& Kwang J. Kim

Group: 1741

Serial No.: 09/899,874

Examiner: Nguyen, Tai V.

Filed: July 5, 2000

Atty. Docket No.: 2313-00

For: SOLID-STATE POLYMERIC SENSORS, TRANSDUCERS, AND ACTUATORS

---

#### **AFFIDAVIT OF DR. MOHSEN SHAHINPOOR**

1. My name is Mohsen Shahinpoor Ph.D. and I am an inventor in the above-referenced patent application.

2. Attached is a copy of my short curriculum vitae.

3. As director of the Artificial Muscle Research Institute, the patents issued to me by the United States Patent and Trademark Office, and the several lectures and publications that I have authored regarding artificial muscles, sensors and actuators, I consider myself an expert in the art.

4. The invention as claimed, is a unique method of manufacturing low-voltage dry electroactive polymeric synthetic muscles for use as sensors, transducers and actuators. The unique method of manufacturing of the low-voltage dry electroactive polymeric sensors, transducers and actuators uses mixing, dry casting and near-boundary particulate loading schemes which is novel and not described or implied in the prior art cited by the Examiner in the referenced office action. Kojima, et al., teaches packaging a valve metal (element 12 in Fig. 1) with dielectric oxide layer (14 in Fig. 1), a conductive layer (16) and conductive polymers (18), carbon layer (20) and a silver paint

layer 22, etc., to create a capacitor (cols. 3 & 4). On top of that the whole assembly has to be in a support electrolyte, which is in liquid form (col. 4 line 51, col. 13, line 28, col. 14, lines 1-10). It is a wet process (col. 4 line 68) and in general water is used (col. 5, lines 22-38), phosphoric acid is also used (col. 5 line 47).

5. I have reviewed the office action regarding the pending patent application dated, May 25, 2004. I strongly disagree with the Examiner's statement that Kojima, et al., discloses a dry electroactive polymeric synthetic muscle and I also disagree that Kojima, et al., teaches the step of providing a polyelectrolyte material as required in claim 1 of the patent application and as defined in the specification. In the office action, the Examiner indicated that a "member conductive polymer" is equivalent to a polyelectrolyte. The Examiner has confused electrolytes and conductive polymers with polyelectrolytes, which are polymer electrolytes or ionic polymers, thus they are completely different substances. Polyelectrolytes are ionic polymers that completely break up into cations and a poly anion (a big multi nodal poly ion of negatively charged network), which neither electrolytes such as table salt NaCl (Na<sup>+</sup>, Cl<sup>-</sup>) nor conductive polymers such as polyaniline are capable of doing. Kojima, et al., does not disclose or imply the use of polyelectrolytes. My argument and opinion are further corroborated in the specification of the pending patent application that defines a polyelectrolyte. See page 2, lines 21-28, page 3I, lines 1-14, page 6, lines 1-4, page 11, line 26. Further, Kojima, et al., teaches that the manufacturing of the capacitor is a "wet" process (col. 4 line 68) and not a dry process as specifically called for in the present patent application claims.

6. The Examiner rejected the claims to the patent application based on a combination of Kojima et al., and Burgess. Burgess describes a tactile sensing transducer for converting tactile pressure into an electrical signal. The present claims are for a unique method of manufacturing low-voltage dry electroactive polymeric synthetic muscles for use as sensors, transducers and actuators, not for tactile sensing.

Burgess discusses a process of making a conductive elastomer by a conductive filler material (old technology of dispersing a metallic or graphite powder phase inside a rubber like material to make it conductive deformable (elastic, rubber), and deforming it to cause changes in conductivity to measure pressure (tactile sensing). See col. 4, lines 26-29. In the present patent application, the finely divided particles in Polyethylene oxide (PEO) is used only to create a surface electrode and not to make the entire (PEO) conductive, as described in Burgess.

7. The third reference cited by the Examiner was Meisel. Again the Examiner has erred by claiming that Meisel discloses a polyelectrolyte material, which is a member of polyethylene oxide family. However, Meisel in col. 5, lines 50-53, does not discuss polyethylene oxide, but just polyethylene, which is not a polyelectrolyte and is just a rubber-like inactive material. The Examiner has confused the substantially different substances polyethylene oxide (PEO) with polyethylene (PE).

8. I am familiar with several publications in similar art areas and the Examiner's conclusions are diametrically opposed to these well regarded authors. I am also familiar with several renowned experts in the art, and they would also vigorously disagree with the Examiner's conclusions and contentions.

  
MOHSEN SHAHINPOOR, Ph.D., PE

STATE OF NEW MEXICO     )  
  )  
COUNTY OF BERNALILLO    )

SUBSCRIBED AND SWORN to before me this 5<sup>th</sup> day of August, by  
Mohsen Shahinpoor, Ph.D., PE.

El C. Bryan  
NOTARY PUBLIC

My Commission Expires:

August 15, 2007



## **MOHSEN (MO) SHAHINPOOR, Ph.D., PE**

Cellular: (505) 975 0888  
Home: (505) 821 3096  
Work: (505) 277 3966

9910 Tanoan Drive, NE  
Albuquerque, NM 87111  
[shah@unm.edu](mailto:shah@unm.edu)

---

### **1. Professional Experience**

#### **Chief Scientist and Director of R&D (7/1/2002-Present)**

Environmental Robots Incorporated  
909 Virginia Av., NE, Suite 205, Albuquerque, NM 87108  
[www.environmental-robots.com](http://www.environmental-robots.com)

**Regents Professor of Mechanical and Aerospace Engineering (8/13/1984-6/30/2002)**  
Department of Mechanical Engineering, School of Engineering  
University of New Mexico, Albuquerque, NM  
[www.me.unm.edu/~shah](http://www.me.unm.edu/~shah)

**Director: Artificial Muscle Research Institute (AMRI) (6/14/1996-6/30/2002)**  
School of Engineering and School of Medicine  
University of New Mexico, Albuquerque, NM  
[www.unm.edu/~amri](http://www.unm.edu/~amri)

**Licensed Professional Engineer (PE) State of New Mexico License No. 9353, (6/16/82-Present), and the State of New York, License No. 58845, (9/15/1982-Present)**

**Consultant:** Sandia National Laboratories, Albuquerque, NM (1/15/1985-9/15/2002)

**Consultant:** Los Alamos National Laboratory, Los Alamos, NM (9/12/1988-8/15/2000)

**Chairman:** Manufacturing Engineering and Robotics, School of Engineering, University of New Mexico, (8/21/1994-8/20/1999)

**Regents Professor (Endowed Chair), School of Engineering and School of Medicine (7/1/1988-6/30/2002)**

**Associate Dean of Engineering, School of Engineering, University of New Mexico, Albuquerque, New Mexico, USA (1/13/1993-1/4/1995)**

**Research Professor, Divisions of Engineering & Applied Science and Geological & Planetary Sciences, California Institute of Technology (CALTECH), Pasadena, California, USA (8/15/91-9/30/93)**

**Halliburton (Endowed Chair) Professor of CAD/CAM, CIM & Robotics**, College of Engineering, University of New Mexico, Albuquerque, New Mexico, USA  
(8/15/87-1/15/91, also 8/15/95-8/15/98)

**Director:** CAD/CAM, CIM & Robotics Laboratories, University of New Mexico, Albuquerque, NM, USA  
(9/14/87-12/31/2000)

**Director:** Intelligent Materials, Structures and Systems Laboratory, University of New Mexico, Albuquerque, NM, USA  
(4/13/92-12/31/2001)

**Chairman & Professor:** Department of Mechanical Engineering The University of New Mexico, Albuquerque, NM, USA  
(8/13/84-6/1/88)

**Chairman:** Manufacturing Engineering & Robotics Undergraduate Program, College of Engineering, The University of New Mexico, Albuquerque, NM, USA  
(9/1/87-12/31/2000)

**Director:** American Society of Mechanical Engineers, ASME, New Mexico Section  
(6/15/1985-8/30/1991)

**Chairman:** Professional Development, American Society of Mechanical Engineers, ASME, New Mexico Section,  
(1/15/1988-9/18/2001)

**Chairman:** Solid Mechanics & Materials Processing Graduate Program, Clarkson University, Potsdam, New York, USA  
(8/30/1982-8/12/1984)

**Co-Director:** Robotics & Manufacturing Center, Clarkson University, Potsdam, New York, USA  
(2/15/1982-8/12/1984)

**Professor:** Department of Mechanical & Industrial Engineering, Clarkson University, Potsdam, NY, USA  
(1/1/1979-8/12/1984)

**Council Member:** US Institute of Colloid and Surface Science, Potsdam, NY, USA  
(1/1/1983-1/1/1986)

**Visiting Principal Scientist:** The Technological Institute, Northwestern University, Evanston, Ill., USA  
(8/1/1978-1/1/1979)

**Associate Dean of Engineering:** College of Engineering, Shiraz University, Shiraz, Iran  
(8/1/1976-8/1/1978)

**Professor:** Department of Mechanical Engineering, Shiraz University, Shiraz, Iran  
(9/1/1976-1/1/1979)

**Principal Research Scientist:** Department of Mechanics & Materials Science, The John Hopkins University, Baltimore, MD, USA  
(6/1/1976-9/1/1976)

**Associate Professor:** Department of Mechanical Engineering, College of Engineering,  
Shiraz University, Shiraz, Iran (9/1/1972-9/1/1976)

**Visiting Associate Professor:** Department of Mechanics & Materials Science, The John  
Hopkins University, Baltimore, MD, USA (9/1/73-9/1/74)

**Chairman:** Department of Mechanical Engineering, Shiraz University, Shiraz, Iran  
(12/15/70-9/1/73)

**Assistant Professor:** Department of Mechanical Engineering, Shiraz University, Shiraz,  
Iran (8/1/70-9/1/72)

**Project Engineer:** De Laval Turbine, Inc., Nuclear Submarine Design Division, Trenton,  
NJ, USA (6/15/68-9/1/68)

**Research Fellow:** Department of Mechanical & Aerospace Engineering, University of  
Delaware, Newark, Del, USA (9/1/68-8/1/70) and (6/15/68-9/1/66)

**Teaching Assistant:** Department of Mechanical & Aerospace Engineering, University of  
Delaware, Newark, DE., USA (9/1/67-6/15/68)

## **2. Education: Listing the Last Attended Institutions First:**

### **Ph.D.: Mechanical and Aerospace Engineering,**

Department of Mechanical and Aerospace Engineering, School of Engineering,  
University of Delaware, Newark, Delaware, USA, Dates of Attendance: 9/1/68 to 6/30/70  
Principal Advisor: H. Fletcher Brown Professor J.L. Nowinski

**Ph.D. Dissertation Title: Free and Forced Large Amplitude Oscillations of  
Homogeneous and Nonhomogeneous Hyperelastic Bodies**

### **M.Sc.: Mechanical and Aerospace Engineering,**

Department of Mechanical and Aerospace Engineering, School of Engineering,  
University of Delaware, Newark, Delaware, USA, Dates of Attendance: 9/1/66 to 6/15/68  
Principal Advisors: Professor Millard F. Beatty and H. Fletcher Brown Professor J.L.  
Nowinski

**Masters Thesis Title: Stability of an Elastic Circular Tube of Arbitrary Wall-  
Thickness Subjected to an External Dynamic Pressure**

## **B.Sc.: Chemical and Materials Engineering**

College of Engineering, Department of Chemical and Materials Engineering, Abadan Institute of Technology, Abadan, Iran, Dates of Attendance: 9/21/62 to 7/1/66

Principal Advisor: Professor H.M. Babayan

**Research Project: Visco-Elastic Properties of Polymeric Melts and Rubbers**

## **3. Academic and Research-HONORS AND AWARDS :**

NASA 2003 “**Space Act Award**” for the Development of A Space Dust Wiper Made With Polymeric Artificial Muscles with Dr. Yosi Bar-Cohen of JPL, October 31<sup>st</sup>., Von Karman Auditorium, NASA Jet Propulsion Laboratories, Awarded by Dr. Charles Elachi.

Elected “**Fellow of IOP**” by President Sir Peter Williams (Fellow of the Royal Society) of the **Institute of Physics**, Great Britain, (2001)

University of New Mexico Libraries “**Faculty Achievement Award**”, (1996)

Elected: **Member of the New York Academy of Sciences**, October (1995)

Received the College of Engineering “**Research Excellence Award**” for the second time, University of New Mexico, May (1995)

**Award For Excellence In Research**, Sandia National Laboratories, Twice in 1993 and 1994.

Awarded by the US Society of Professional Engineers, New Mexico Section, the title “**Engineer of the Year 1992**”.

New York Times 1991 Selected Inventor : The “**Magic Wheel**”, August 17, (1991)

**Award For Excellence In Manufacturing Engineering Education**, Society of Manufacturing Engineers, April, 1991

Albuquerque Journal's 1991 selected “**Rising Stars of the 90's**”

Awarded by the Board of Regents of the University of New Mexico, the title of “**Chaired Regents Professor for Life**”, (1990)

Elected “**Fellow of ASME**” by the Board of Governors of the American Society of Mechanical Engineers, (1989)



Awarded the "**Halliburton Endowed Chair Professorship in CAD/CAM, CIM & Robotics**", in the School of Engineering, University of New Mexico, August (1988)

Received the College of Engineering "**Research Excellence Award**", University of New Mexico, May (1988)

Awarded the University of New Mexico's Burlington Northern Foundation "**Faculty Achievement Award for Excellence in Teaching and Research**", May (1986).

**Award of Achievement** by the U.S. Society of Technical Communications, for the Creation in 1984 of the World's First Multi-Station Robotics Instructional Laboratory at UNM, April (1986), USA.

Elected: **Member of the Sigma Xi Scientific Research Society**, (March 1985).

Awarded "**Eminent Engineer**" title by the U.S. National Engineering Honor Society; November 1983, USA

**First Prize:** International Union of Theoretical & Applied Mechanics (IUTAM)-Applied Mechanics Reviews International Jumping Disk Contest, Toronto, Canada; August 1980

**Engineering Researcher of the Year 1977** Award, selected jointly by the "Academy of Sciences of Iran" and "Ministry of Science and Higher Education of Iran", Tehran, Iran; 10/9/77

Alborz Foundation "**Distinguished Scientist of the Year 1976**" Award, Tehran, Iran; 2/7/77

**4<sup>th</sup>. Place Honor** (amongst over 100,000 high school applicants), National Universities Annual Admissions Contest, Tehran, Iran (1962)

#### **4. College and Departmental Academic Services:**

**Chairman:** Research Excellence Committee, School of Engineering, UNM, (1992, 1994, 1996)

**Chairman** and/or **Member:** Appointment, Promotion and Tenure Committee, Department of Mechanical Engineering, UNM, (1994-1997, 1999-2002)

**Chairman** and/or **Member:** Faculty Search Committee, Department of Mechanical Engineering, UNM, (1988, 1996, 1999, 2001)

**Chairman:** Civil Engineering Chairman Search Committee, School of Engineering, UNM, (1998-1999)

**Chairman** and/or **Member**: Graduate Committee, Department of Mechanical Engineering, UNM, (1988, 1992, 1999, 2000)

**Chairman** and/or **Member**: Mechanical Engineering Chairman Search Committee, School of Engineering, UNM, (1988, 1993)

## **5. Laboratories Established (most recent ones listed first)**

Established with funding from Neurological Surgery Department and the School of Medicine of the University of New Mexico during the year 1998 World's first "**Spine Biomechatronics Laboratory**". First attempt to electronically regenerate severed spinal cord was conducted in this laboratory in September of 2000.

Established with funding from Sandia National Laboratories and University of New Mexico Office of the Associate Provost for Research the **Artificial Muscles Research Institute (AMRI)** during the year 1996 in the School of Engineering and the School of Medicine, University of New Mexico. World's first membrane-encapsulated artificial muscles made from ionic polymeric gels were first fabricated in the "**Artificial Muscle Research Laboratory**", (AMRL), which was established prior to the establishment of the **Artificial Muscles Research Institute (AMRI)** laboratory in 1993.

Established with funding from Sandia National Laboratories and US Army Research Office (ARO) a "**Smart Materials, Structures and Systems Laboratory**" during the year 1992 in the College of Engineering, University of New Mexico. World's first membrane-encapsulated artificial muscles made from ionic polymeric gels were first fabricated in this laboratory in 1993.

Established (with Professor Doug Smith of Chemical and Nuclear Engineering Dept.) as a Co-Director, the first UNM "**Powder and Granular Materials Laboratory**" jointly run by the Mechanical Engineering and the Chemical and Nuclear Engineering Departments during the period 1984 - 1985.

Established with external funds (NSF) a "**Granular Materials Research Laboratory**" in the Mechanical and Industrial Engineering Department at Clarkson University during the Period 1980 - 1983.

## **6. Recent Activities In Conferences, Congresses and Professional Societies (listing the most recent ones first)**

**Chairman**: Membership and Marketing Committee, New Mexico Biotechnology and Biomedical Association (NMBBA), Albuquerque and Santa Fe, NM (2004-2006)

**Member of the Board of Directors:** New Mexico Biotechnology and Biomedical Association (NMBBA), Albuquerque and Santa Fe, NM (2004-2006)

**General Chairman** with Noble Laureate Professor Pierre Gilles De Gennes: Second World Congress on Biomimetics and Artificial Muscles (Biomimetics and Nano-Bio 2004, [www.world-congress.net](http://www.world-congress.net)), April 25-28, (2004), Williamsburg, VA, USA

**Member:** NM Biotechnology & Biomedical Association (NMBBA), (2002)

**Member:** Biomaterials Network, (2002)

**General Co-Chairman** with Noble Laureate Professor Pierre Gilles De Gennes: First World Congress on Biomimetics and Artificial Muscles (Biomimetics 2002, [www.world-congress.net](http://www.world-congress.net)), December 9-11, (2002), Albuquerque Convention center, Albuquerque, New Mexico, USA

**Fellow:** Institute of Physics, IOP, (2001)

**Member of the Electroactive Polymer Actuators and Devices Program Committee,** SPIE 1997-2002 North American Congress on Smart Structures and Materials, San Diego, California, March (1997-Present)

**Member of the International Program Committee,** 1997 IEEE Robotics & Automation Conference, (1997)

**Member:** New York Academy of Sciences (1997-Present)

**Member of the Smart Materials Program Committee,** SPIE 1997 North American Congress on Smart Structures and Materials, San Diego, California, February (1997-2002)

**Session Chair,** Smart Materials, SPIE (1997) North American Congress on Smart Structures and Materials, San Diego, California, February (1997)

**Member of the International Advisory Board of the 4<sup>th</sup>. International Conference on Intelligent Materials,** ICIM'97 June (1997), Tokyo, Japan

**Licensed Professional Engineer** (New Mexico State), License No. 9353 and (New York State), License No. 58845, (1984-Present)

**Program Chair:** National Science Foundation's 1996 Design and Manufacturing Grantees Conference, January 1996

**Member:** US National Committee on Vibrations and Noise, (1994-1996)

**Member:** Smart Materials Program Committee, SPIE 1996 North American Congress on Smart Structures and Materials, San Diego, California, February (1996)

**Session Chair,** Smart Materials, SPIE 1996 North American Congress on Smart Structures and Materials, San Diego, California, February (1996)

**Member:** International Advisory Board of the 3rd. International Conference on Intelligent Materials, ICIM'96 and 3rd. European Conference on Smart Structures and Materials, June 3-5, (1996), Lyon, France

**Chairman:** Technical Program Committee, Fourth International Congress on Environmentally Conscious Design and Manufacturing, July 23-25 ,Cleveland, Ohio, (1996)

**Chairman:** Technical Program Committee, Fourth International Congress on Environmentally Conscious Design and Manufacturing, July 23-25 ,Cleveland, Ohio, (1996)

**Member of the National Science Foundation Panel:** Design & Manufacturing (1995-Present)

**Co-Chairman:** The Technical Program Committee of the Second Sandia-UNM-ASME Agile Manufacturing Conference on Virtual Manufacturing, March 1995, Albuquerque, New Mexico.

**Member:** The Smart Materials Program Committee, SPIE 1995 North American Congress on Smart Structures and Materials, San Diego, California, February-March (1995)

**Member:** American Institute of Aeronautics and Astronautics, AIAA (1994)

**Symposium Chair:** Smart Materials, SPIE 1995 North American Congress on Smart Structures and Materials, San Diego, California, February-March (1995)

**Co-Chairman:** Second International Congress on Environmentally Conscious Manufacturing, August 29-September 3, Arlington, Virginia, (1993)

**Co-Chairman:** The Technical Program Committee of the First Sandia-UNM-ASME Agile Manufacturing Conference on Rapid Prototyping, October 1993, Albuquerque, New Mexico.

**Member:** The Smart Materials Program Committee, SPIE 1993 North American Congress on Smart Structures and Materials, Albuquerque, New Mexico, February (1993)

**Symposium Chair:** Smart Materials, SPIE 1993 North American Congress on Smart Structures and Materials, Albuquerque, New Mexico, February (1993)

**Member:** US National Stirring Committee, 14th. Biennial ASME Vibrations Conference, Albuquerque, NM, September (1993)

**Cluster Chair:** Vibrations and Dynamics of Flexible Robot Manipulators, the 14th. Biennial ASME Vibrations Conference, Albuquerque, NM, September (1993)

**Cluster Chair:** Smart Materials and Structures, the 14th. Biennial ASME Vibrations Conference, Albuquerque, NM, September (1993)

**Co-Chairman:** Local Program Committee and Member of the International Program Committee of International Symposium of Robotics and Manufacturing : Recent Trends in Research, Education and Applications, October, (1992), Santa Fe, New Mexico

**Member:** The Smart Materials Program Committee of The First International Congress on Smart Materials and Structures, Alexandria, Virginia, November, (1992)

**Co-Chairman:** First International Congress on Environmentally Conscious Manufacturing, September 17-20, Santa Fe New Mexico, (1991)

**Co-Chairman:** 27th. Annual Conference of Society of Engineering Science, October 21-26, (1990), Santa Fe, New Mexico

**Chairman & Session Organizer:** Reactive Particle Systems, 20th. FPS Powder Science & Technology International Symposium, Boston, MA, August (1989)

**Co-Chairman:** 27th. ASME National Symposium on " Hazardous Waste-Impact Mitigation Through Innovative Technology, Albuquerque, New Mexico, May (1989)

**Member:** International Program Committee, Second International Symposium on "Robotics and Manufacturing," Albuquerque, NM, November (1988)

**Chairman and Session Organizer:** Reactive Particles, 19th. FPS Powder Science and Technology Symposium, Santa Clara, Cal., July (1988)

**Program Chairman:** 26th ASME Symposium on "New Trends In Automated Manufacturing," Albuquerque, NM, May (1987)

**Session Organizer and Chairman:** IEEE-ISE International Symposium, Albuquerque, NM, May (1987)

**Session Chairman:** IASTED International Symposium on Robotics and Automation, Santa Barbara, CA, May (1987)

**Co-Chairman:** The National Program Committee and member of the International Program Committee of International Symposium of Robotics: Modeling, Control, and Education, Nov. (1986), Albuquerque, N.M.

**Program Chairman:** ASME National Symposium on "Intelligent Machines and Robotics", Albuquerque, NM, May (1986).

**Session Chairman:** Robot Engineering Education, ASME National Symposium on "Intelligent Machines and Robotics", Albuquerque, NM, May (1986).

**Session Co-Chairman:** Pore Characterization of Powders and Granular Materials, Fine Powder Society's Annual Conference, San Francisco, Calif., July (1986).

**Member:** International Pyrotechnics Society, (1986-Present), USA

**Fellow:** American Society of Mechanical Engineers, (1986), ASME

**Member:** Tau Beta Pi, Engineering Honor Society, (1986), (USA)

**Member:** Sigma Xi, The Scientific Research Society, (1986), (USA)

**Director:** ASME, New Mexico Section, (1985-1992)

**Site Proctor:** IEEE National Video Conference, "Robot Dynamics and Control", Albuquerque, NM, February (1985).

**Senior Member:** Society of Manufacturing Engineers, (1985-Present), USA

**Member:** Industrial Mathematics Society, (1985-Present), USA

**Member:** New Mexico Academy of Sciences, Santa Fe, NM, (1984-Present)

**Member:** American Society for the Advancement of Science, (1984-Present), USA

**Member:** U.S. Institute of Colloid & Surface Sciences, (1982-Present), USA

**Member:** The American Academy of Mechanics, (1982-Present), USA

**Member:** U.S. National Society of Professional Engineers (NSPE) New Mexico Section and New York Section, (1982-Present), USA

**Member:** International Fine Particle Society, (1981-Present), USA

**Member:** The Society of Engineering Science, (1981-Present), USA

**Member:** Society for Natural Philosophy, (1974-Present), USA

## **7. Inventions:**

### **Foreign Patents**

"Cholesteric Liquid Crystal Chromo-Pressure Gauge", U.S.-Int. Inv. Inc., No. A-316-747, Iran Patent Office, No. **12393/53-8-29**, Tehran, Iran (1975)

"Pistachio-Sorting Machine", Iran Patent Office, No. **13197/53-3-29**, Tehran, Iran (1975)

"Liquid Crystal Writing Board", Iran, Patent Office, No. **13853/54-8-27**, Tehran, Iran (1976)

"Network of Oscillating Jets for Passive Irrigation", Iran Patent Office, No. **13854/54-8-27**, Tehran, Iran (1976)

"Inertial Solar Engine", Iran Patent Office, No. **16615/54- 11-5**, Tehran, Iran (1977)

### **US Patents (listing the most recent ones first)**

"Synthetic Muscle-Based Diaphragm Pump Apparatuses", *US Patent Office*, United States Patent No. **6,682,500**, Issued January 27, 2004.

"Disk Drive Optical Switch", *US Patent Office*, United State Patent No. **6,678,434**, Issued January 13, 2004.

"Shape Memory Alloy Temperature Sensor", *US Patent Office*, United State Patent No. **6,612,739**, Issued September 2, 2003.

"Implantable Micro-Pump Assembly," , *US Patent Office No.* **6,589,198**, Issued July 8, 2003.

"Surgical Correction of Human Eye Refractive Errors By Active Composite Artificial Muscle Implants", *US Patent Office*, No. **6,511,508** Issued January 28, 2003, also PCT Application No. **2323-00-PCT** filed July (2001).

"Ionic Polymer Sensors and Actuators", *US Patent Office*, No. **6,475,639**, Issued November 5, 2002.

"Electrically-Controllable Multi-Fingered Resilient Heart Compression Devices", *US*

*Patent Office*, Number **6,464,655**, Issued October 15, 2002.

"Smart Fiber Optic Magnetometer", *US Patent Office*, Number **6,433,543**, Issued , August 13, 2002.

"Metal Hydride Artificial Muscles," , *US Patent Office*, United State Patent **6,405,532**, Issued June 18, 2002.

"Dynamic Multi-Channel Fiber Optic Switch", *US Patent Office*, United State Patent, **6,381,382**, Issued April 30, 2002.

"Dynamic Fiber Optic Switch with Artificial Muscles", *US Patent Office*, United States Patent **6,192,171**, Issued February 20, 2001.

"Dynamic Fiber Optic Switch", *US Patent Office*, United States Patent **6,181,844**, Issued January 30, 2001.

"Soft Actuators and Artificial Muscles" , *US Patent Office*, United States Patent **6,109,852**, Issued August 29, 2000.

"Fibrous, Parallel Spring-Loaded Shape-Memory Alloy (SMA) Robotic Linear Actuators", *US Patent Office*, United States Patent **5,821,664**, Issued October 13, 1998.

"Shape Memory Alloy Thaw Sensors", *US Patent Office*, US Patent Number **5,735,607**, Issued April 7, 1998.

"Omni-Directional Electromagnetic Rail Launchers", *US Patent Office*, US Patent No. **5,435,225**, Issued July 25, 1995.

"Spring-Loaded Ionic Polymeric Gel Linear Actuator", *US Patent Office*, US Patent No. **5,389,222**, Issued February 14, 1995.

"Hybrid Armature Projectile", *US Patent Office*, US Patent No. **5,191,164**, Issued March 2, 1993.

"Electrically Controlled Polymeric Gel Actuators", (world's first patent on synthetic artificial muscles), *US Patent Office*, US Patent No. **5,250,167**, Issued October, 5, 1993.

"Robotic Apparatus", *US Patent Office*, US Patent No. **5,114,300**, Issued May 19, 1992.

"Deployable Spatial Structure", *US Patent Office*, United States Patent **5,038,532**, Issued August 13, 1991, "The Magic Wheel", New York Times selected Invention of 1991, August 17, 1991.



## **8. Refereed Research Publications In Journals, Edited Books, Book Chapters and Encyclopedias (listing the most recent ones first)**

Shahinpoor, "Continuum Electromechanics of Ionic Polymeric Gels As Artificial Muscles For Robotic Applications," , Smart Materials & Structures Int. J., vol.3, pp. 367-372, (1994);

Shahinpoor, M. and M.S. Thompson, "The Venus Flytrap As A Model For Biomimetic Material With Built-In Sensors and Actuators," , J. Materials Science & Engineering, vol.C2, pp. 229-233, (1995)

Shahinpoor, M., "Micro-Electro-Mechanics of Ionic Polymeric Gels As Electrically-Controllable Artificial Muscles," , Int. J. Intelligent Material Systems, vol. 6, no. 3, pp. 307-314, (1995)

Shahinpoor, M.,, "Design and Development of Micro-Actuators Using Ionic Polymeric Micro-Muscles," , Proc. ASME Design Engn. Technical Conference, Boston, MA, September (1995)

Shahinpoor, M., and Y. Osada, "Heart tissue Replacement with Ionic Polymeric Gels" Proc. 1996 ASME Winter Annual Meeting, San Francisco, California, November 12-18, (1995)

Shahinpoor, M.,, " Ionic Polymeric Gels As Artificial Muscles For Robotic and Medical Applications, Int. Journal of Science & Technology vol. 20, no. 1, Transaction B, pp. 89-136, (1996)

Shahinpoor, M., "Active Polyelectrolyte gels As electrically-Controllable Artificial Muscles and Intelligent Network Structure," , Book Chapter in Structronic Systems, Part II, edited by : H.S.Tzou, A. Guran, U. Gabbert, J. Tani and E. Breitbach, World Scientific Publishers, London, pp. 31-85, (1998)

Shahinpoor, M., Y. Bar-Cohen, J. Simpson and J. Smith, " Ionic Polymer-Metal Composites (IPMC's) As Biomimetic Sensors, Actuators and Artificial Muscles-A Review," , Smart Materials & Structures Journal, vol. 7, pp. R15-R30, (1998)

Kim, K.J., and M. Shahinpoor and R. Razani, "Solid Polymer Fuel Cells for the Next Century," , Int. J. Environ. Conscious Design & Manufacturing, Vol. 7, No. 3, pp. 17-46, (1998)

Shahinpoor, M., "Ion-Exchange Membrane-Metal Composite As Biomimetic Sensors and Actuators," in Polymer Sensors and Actuators, Edited by Y. Osada and D. De Rossi, Springer-Verlag-Heidelberg, (1999)

M. Shahinpoor, Y. Bar-Cohen, J. Simpson and J. Smith, " Ionic Polymer-Metal Composites (IPMC's) As Biomimetic Sensors and Actuators," in Field-Responsive Polymers, American Chemical Society Publication, ACS-FRP, Edited by J. Simpson and I.M. Khan, Pending Publications, (1999)

L. Ferrara, M. Shahinpoor, K. J. Kim, B. Schreyer, A. Keshavarzi, E. Benzel Jeffrey Lantz, " Use of ionic polymer-metal composites (IPMCs) as a pressure and transducer in the human spine, ", in Proc. SPIE Smart Materials and Structures Conference, March 1-5, 1999, New Port Beach, California, Publication No. SPIE 3669-45, (1999)

R. Lumia and M. Shahinpoor, " Microgripper Design Using Electro-Active Polymers, " in Proc. SPIE Smart Materials and Structures Conference, March 1-5, 1999, New Port Beach, California, Publication No. SPIE 3669-30, (1999)

Y. Bar-Cohen, S.P. Leary, M. Shahinpoor, J.O. Simpson and J. Smith, "Flexible Low-Mass Devices and Mechanisms Actuated by Electro-Active Polymers, " , in Proc. SPIE Smart Materials and Structures Conference, March 1-5, 1999, New Port Beach, California, Publication No. SPIE 3669-38, (1999)

M. Shahinpoor, "Ionic Polymer Metal Composite As Biomimetic Sensors and Actuators, " Proc. 44<sup>th</sup>. Int. SAMPE Symposium, Edited by : Dr. Leslie J. Cohen, Jerome, L. Bauer and William E. Davis, Published by SAMPE, pp. 1950-1960, May 23-27, Long Beach, California, (1999)

M. Shahinpoor and K.J. Kim, "The Effect of Surface-Electrode Resistance on the Performance of Ionic Polymer-Metal Composite (IPMC) Artificial Muscle," , Smart Materials and Structures Int. Journal, vol. 9, pp. 1-9, (2000)

K.J. Kim and M. Shahinpoor, " Artificial Sarcomere and Muscle made With Conductive Polyacrylonitrile (C-PAN) Fiber Bundles," in Proc. SPIE Smart Materials and Structures Conference, March 4-9, 2000, New Port Beach, California, Publication No. SPIE 3987-35, (2000)

M. Shahinpoor, " Electrically-Activated Artificial Muscles Made With Liquid Crystal Elastomers," in Proc. SPIE Smart Materials and Structures Conference, March 4-9, 2000, New Port Beach, California, Publication No. SPIE 3987-27, (2000)

M. Shahinpoor, "Ion-Exchange Membrane-Metal Composite As Biomimetic Sensors and Actuators, " Book Chapter, Chapter 12, in *Polymer Sensors and Actuators*, Edited by Y. Osada and D. De Rossi, *Springer-Verlag-Heidelberg*, pp.325-359, (2000)

H. B. Schreyer, N. Gebhart, K. J. Kim, and M. Shahinpoor, "Electric Activation of Artificial Muscles Containing Polyacrylonitrile Gel Fibers," , *Biomacromolecules*, Vol. No. 4, pp. 642-647, (2000)

A.R. Motamedi., Blevins, F.T., Willis, M.C. , McNally, T.P., Shahinpoor, M., "Biomechanics of the Coracoclavicular Ligament Complex and Augmentations Used in Its Repair and Reconstruction," *AM J. SPORTS MEDICINE* , vol. 28, No.3, pp. 380-384, (2000)

M. Shahinpoor and K. J. Kim, "Ionic Polymer-Metal Composites – I. Fundamentals," (Review Paper), *Smart Materials and Structures Int. J.*, Vol. 10, pp. 819-833 (2001)

M. Shahinpoor and K. J. Kim, "A Solid-State Soft Actuator Exhibiting Large Electromechanical Effect," *Applied Physics Letters (APL)*, vol. 80, Number 18, pp. 3445-3447, May (2002)

M. Shahinpoor and K. J. Kim, " Novel Ionic Polymer-Metal Composites Equipped with Physically-Loaded Particulate Electrode As Biomimetic Sensors, Actuators and Artificial Muscles," *Actuators and Sensors A, Physical*, **96 (2/3)** A, 3163, pp. 125-132, (2002)

K. J. Kim and M. Shahinpoor, "A Novel Method of Manufacturing Three-Dimensional Ionic Polymer-Metal Composites (IPMC's) Biomimetic Sensors, Actuators and Artificial Muscle," *Polymer*, Vol. 43/3, pp.797-802 (2002)

K. J. Kim and M. Shahinpoor, "Application of Polyelectrolytes in Ionic Polymeric Sensors, Actuators, and Artificial Muscles," Review Chapter in *Handbook of Polyelectrolytes and their Applications*, edited by S. K. Tripathy, J. Kumar and H. S. Nalwa, vol. 3; Applications of Polyelectrolytes and Theoretical Models, **American Scientific Publishers**, (2002)

Moheb S. Moneim, Keikhosrow Firoozbakhsh, Abdol-Azim Mustapha, Kenna Larsen and Mohsen Shahinpoor, "Flexor Tendon Repair Using Shape Memory Alloy Suture," *J. Clinical Orthopaedics and Related Research*, vol. 402, pp. 251-259, September (2002)

M. Shahinpoor and K. J. Kim, " Experimental Study of Ionic Polymer-Metal Composites in Various Cation Forms: Actuator Behavior", **Science and Engineering of Composite Materials**, Volume 10, No. 6, pp. 423-436, (2002)

J. Tyson, T. Schmidt, M. Shahinpoor and K. Galanulis, "Biomechanics Deformation and Strain Measurements with 3D Image Correlation Photogrammetry," **Journal of Experimental Techniques**, Society for Experimental Mechanics, accepted for publications (to appear 2004)

M. Shahinpoor, "Artificial Muscles," Chapter in *Encyclopedia of Biomaterials and Biomedical Engineering*, edited by G. Wnek and G. Bowlin, **Marcel Dekker Publishers**, (to appear 2004)

M. Shahinpoor, "Electroactive Ion Containing Polymers," Chapter in *Hand Book of Smart Systems*, Institute of Physics (IOP) Publication, London, England, (to appear 2004)

M. Shahinpoor, "Mechanoelectrical Phenomena in Ionic Polymers," *Journal of Mathematics and Mechanics of Solids*, Special issue in honor of Professor Millard F. Beatty, vol. 8, No. 3, pp. 281-188, June (2003)

K. J. Kim and M. Shahinpoor, "Effective Diffusivity of Nanoscale Ion-Water Clusters within Ion-Exchange Membranes Determined by a Novel Mechano-Electrical Technique," *International Journal of Hydrogen Energy*, vol.28, No. 1, pp. 99-104, (2003)

M. Shahinpoor, K. J. Kim, and D. Leo, "Ionic Polymer-Metal Composites as Multifunctional Materials," *Polymer Composites*, Volume 24, No. 1, pp. 24-33, (2003)

K. J. Kim and M. Shahinpoor, "Ionic Polymer-Metal Composites – II. Manufacturing Techniques", *Smart Materials and Structures (SMS)*, Institute of Physics Publication, Vol. 12, No. 1, pp. 65-79, (2003)

G.M. Lloyd, K/J/ Kim, A. Razani and M. Shahinpoor, " Investigation of A Solar-Thermal Bio-Mimetic Metal Hydride Actuator," *ASME Journal of Solar Energy Engineering*, Vol. 125, pp. 95-100, February (2003)

M. Shahinpoor, " Ionic Polymer-Conductor Composites As Biomimetic Sensors, Robotic Actuators and Artificial Muscles-A Review," *Electrochimica Acta*, Vol. 48, No. 14-16, pp. 2343-2353, (2003)

M. Shahinpoor and A. Guran, "Ionic Polymer-Conductor Composites (IPCC) as Biomimetic Sensors, Actuators and Artificial Muscles , **SELECTED TOPICS IN STRUCTRONICS AND MECHATRONIC SYSTEMS**, Editors: A. Belyaev and A. Guran, pp. 417-436, World Scientific Publishers, London, (2003)

M. Shahinpoor and K. J. Kim, "Effects of Counter-ions on the Performance of Ionic Polymer-Metal Composite Artificial Muscles," *Biomacromolecules*, accepted for publication (to appear 2004)

M. Shahinpoor and K. J. Kim, "Mass Transfer Induced Hydraulic Actuation in Ionic Polymer-Metal Composites," *Journal of Intelligent Materials Systems and Structures (JIMSS)*, accepted for publication (to appear 2004)